Final Report

Synoptic Climatology of Space-Based Water Vapor Measurements

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This report summarizes research performed under the grant listed above. Funding was originally anticipated for a three-year period, 2/92 - 1/95. Due to federal budget cuts, only the first two years of funds were eventually available to the project. Through a no-cost extension, activities were continued after the second project year, though at a much reduced level.

Research proceeded in three areas: (a) statistical modeling of water vapor variability due to baroclinic dynamics, (b) occurrence of concentrated water vapor structures, (c) modulation of baroclinic dynamics by water vapor.

(a) Statistical modeling

The principal focus of this grant was the analysis of a precipitable water (PW) data set retrieved by Dr. Graeme Stephens and colleagues using SSM/I radiances. Daily data for two seasons were available: June - August 1988 and December 1988 - February 1989. The dynamics of the Southern Hemisphere extratropics are dominated by transient, baroclinic waves (e.g., Randel and Stanford, 1985, *J. Atmos. Sci.*, **42**, 1172-1188), raising the question of how much these waves control the water cycle in this region. The PI and graduate assistants approached this issue by comparing the daily, weekly and monthly variability of PW with concomitant fluctuations in near-surface air temperature. For both the total and eddy water fields, there was a close correspondence between PW and the temperature, especially for synoptic and planetary scale transient eddies (Gutowski et al , 1995). The results support a typical modeling assumption that transient eddy moisture fields are proportional to transient eddy temperature fields under the assumption of constant relative humidity. The implication from this study is that transient, baroclinic eddy dynamics can describe much of the water vapor variability in the Southern extratropics.

(b) Concentrated water vapor structures

This project was begun during the initial period of the grant. The nature of the analysis renders it suitable for senior thesis research by undergraduate meteorology majors, and so it was decided to continue the effort at a low level of activity beyond the funded grant period. Newell et al. (1992; *Geoph. Res. Let.*, **12**, 2401-2404) described the appearance of "tropospheric rivers" that occur when water vapor transport occurs in concentrated, elongated zones. We are using the PW data set to explore whether or not these transport structures imply extended structures in the water vapor field itself. Exploration to date (Boyd, 1995) for extended structures shows that they

- occur quite readily at all extratropical latitudes
- have mean lengths of about 1500 km
- tend to be oriented northwest-southeast
- last about 1 - 2 days
- undergo rotation by the climatological, low-level zonal wind

The last two features in particular are not consistent with the findings by Newell et al. (1992) for water vapor flux structures, indicating that the behavior they have observed is the outcome of atmospheric dynamics rather than atmospheric water vapor distribution.

(c) Modulation of baroclinic dynamics by water vapor

This project was the Creative Component for a Master's Degree student in the Iowa State Statistics Department, Ms. Betsy Uken. It addressed the question: do seasonal variations in atmospheric water vapor amount modulate fluctuations of transient eddy magnitudes? The motivation for this study was that simple dynamics models show that the variability could be rather sensitive to how strongly radiation cools the troposphere, with weak cooling yielding slower variation in eddy magnitudes. Because water vapor is the primary greenhouse gas in the Earth's atmosphere, this cooling can be sensitive to the amount of water vapor present.

The PI and Ms. Uken studied the variability of baroclinic eddy dynamics in the Southern Hemisphere's extratropics, using the zonal and vertical average of the meridional eddy heat flux as a measure of the strength of baroclinic energy-conversion processes and transient eddy behavior. We contrasted the eddy flux variability in moist and dry seasons, where a dry season in the Southern Hemisphere is the months June-July-August-September and a wet season is the months December-January- February-March. The meridional temperature gradient also can affect baroclinic eddy dynamics, and the gradient also changes between the wet and dry seasons defined here. However, in the Southern Hemisphere mid-latitudes, the seasonal change in temperature gradient is much weaker than it is in the Northern Hemisphere, so the analysis assumed that the water vapor influence would be the more prominent factor.

We analyzed the eddy heat flux variability by computing temporal fourier series of the zonally and vertically integrated flux. To answer our question, we looked for significant differences in the shape of the spectra between dry and wet seasons. At latitudes 25 S - 35 S, wet season spectra were shifted toward lower frequency fluctuations compared to corresponding dry season spectra. This behavior was in accord with expectations from the simple dynamics models. However, at latitudes 50 S - 55 S, the opposite behavior occurred. Because the results were not conclusive in either supporting or refuting the results from simple dynamics models, a more definitive conclusion awaits the analysis of GCM simulations being performed under another contract.

2. Publications, Reports and Presentations

Gutowski, W. J., E. A. Lindemulder, K. Jovaag, 1995: Temperature-dependent daily variability of precipitable water in SSM/I observations. *J. Geophys. Res.*, **100**, 22,971-22,980.

Boyd, K., 1995: *Extended structures of Atmospheric Water Vapor in SSM/I Data*, Senior Thesis, Iowa State University, 20 pp.

Uken, E. A., 1994: *Spectral Analysis of Atmospheric Heat Flux in the Southern Hemisphere*, MS Creative Component, Iowa State University, 111 pp.

Gutowski, W. J., E. A. Uken, and K. A. Jovaag, 1994: Remote sensing of the atmosphere's hydrologic cycle, *106th Annual Meeting, Iowa Academy of Science,* 22-23 April 1994, Davenport, Iowa.

Gutowski, W. J., and L. E. Branscome, 1993: Hydrologic and radiative feedbacks on extratropical transient eddies: Implications of global warming, *Seventeenth Stanstead Seminar: The role of large-scale, extratropical dynamics in global climate change*, 13-18 June, 1993, Lennoxville, Québec, Canada.

Gutowski, W. J., and E. A. Uken, 1993: Synoptic Dynamics of the Southern Hemisphere, Extratropical Water Vapor Cycle Revealed by SSM/I Retrievals and NMC Analyses, *Fourth International Conference on Southern Hemisphere Meteorology and Oceanography*, 29 March - 2 April 1993, Hobart, Australia.